Project no.:
241382

Project acronym

ATEsT

Project title:

Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System

Instrument: Coordination and Support Action
Thematic priority: ENERGY.2009.9.1.1
European Energy Infrastructure Networks and Systems Transition Planning
Start date of project: 01 October 2009
Duration: 30 months

Description of the approach on Linking Models

March 2012

Organisation name of WP Coordinator for this deliverable:
CRES

Author(s)		
Name	**Organisation**	**E-mail**
Christos Nakos	CRES	cnakos@cres.gr
George Giannakidis	CRES	ggian@cres.gr

Acknowledgements

This project was funded by the European Commission under the 7th Framework Program (Grant Agreement No. 241382). The authors would like to acknowledge many colleagues within the ATEsT project team for providing useful inputs and comments during the process leading to this report. In particular, we are grateful to Rodica Sandu and Sophia Simoes (JRC), Koen Schoots, Joost van Stralen (ECN), Oscar Amerighi, Maria Cristina Tommasino, Umberto Ciorba (ENEA), Nazmiye Ozkan, Elisabetta Mocca (PSI), Annele Eerola, Tiina Koljonen, Nina Wessberg (VTT), Ralf Kuder, Markus Blesl (IER), Helena Cabal (CIEMAT) and Drazen Jaksic (EIHP), for their inputs and comments.

The authors are responsible for all remaining errors and omissions.

Contents

1. Introduction

According to the initial planning of the ATEsT project, WP3 was aimed to provide the "ultimate" list of models/tools that could be used for transition planning and analysis of the development of energy systems. This list of tools would then be used in order to analyze existing data and data deficiencies in WP4, and in WP5 the soft-linking of complementary models and tools that provide useful information for decision makers would be attempted. However, in the report "Models/Tools selection methodology", which was the output of WP3 of the project, it was stated that the models which are appropriate for answering a policy question depend heavily on the policy question itself, meaning that the "best available" models are a function of the question to be answered. In order to achieve the aim of WP5, the project team has decided to choose a number of models and tools that appeared in different plausible combinations in the WP3 analysis, and developed a linking scheme for these models. The policy questions used in the analysis of WP3 were:

1. How to achieve a low cost and low emissions energy mix ?
2. How to achieve an energy mix that maximizes employment opportunities ?
3. How to achieve an energy mix that has the maximum societal acceptance ?
4. Which are the most competitive low carbon technologies in the medium and long term ?
5. Where should new energy installations be best located ?
6. In which R&D areas should a country invest ?
7. How should a country develop energy interconnections with other European and non European countries ?
8. How to improve energy efficiency ?

For each one of these, the methodology of WP3 produced a number of model combinations, ranking them according to the ranking of each model (Section 3 of the "Models/Tools Selection Methodology" report). The top combinations for each question were:

Policy Question	Top combination of models
1	GEME3, IER_Transmission, MDM-E3, RESOLVE-E, Horizonscan, Climate Bonus
2	IER_Transmission, MDM-E3, RESOLVE-E, STSc, Horizonscan, More_Hys
3	COMPETES, IER_Transmission, STSc, MECHanisms, Behave, Climate Bonus
4	NEMESIS, POLES, IMAGE-TIMER, Horizonscan, iKnow,SAMLAST
5	TIMES, COMPETES, IER_Transmission, STSc, MECHanisms, Climate Bonus
6	GEME3, PRIMES, COMPETES, RESOLVE-E, STSc, Horizonscan
7	NEMESIS, POLES, COMPETES, Horizonscan, iKnow, SAMLAST
8	GEME3, IER_Transmission, MDM-E3, RESOLVE-E, Horizonscan, Climate Bonus

From this list of top combinations the models that were available to the project partners were chosen, in order to ensure that there is a very detailed knowledge of both required input data and produced results, which is necessary in order to go into the required detail of a linking scheme

Section 2 of this report presents a brief description of the selected models, while Appendix I details the input data and outputs which were compiled for the model linking procedure. Section 3 gives an overview of theoretical concepts and applications of linking approaches in the literature. Section 4 presents the linking scheme that is developed by the team. It should be noted that a complete soft-linking of these models/tools was not possible within the framework of this project (and is beyond the scope of the project), since some of these models exist only on a specific country level (i.e. Germany for IER-Transmission) and some others must be applied to specific small scale projects (i.e. MECHanisms). So the approach adopted was to study and present the pre-requisites of a possible linking.

In most of the top model combination that appeared in the process of WP3, a CGE model was always included (e.g. GEM-E3). The process of using the output of a CGE model as input to bottom-up models and the process of hard linking the two approaches have been applied in the past, as shown by selected references in the next sections. For this reason, it was decided in this project to focus on model couplings that were not done in the past by examining other soft linking possibilities between the selected models.

2. Short description of the models in the linking exercise

The models/tools which were selected to be used in the linking exercise in order to demonstrate potential linking procedures and their challenges are TIMES, COMPETES, Climate Bonus, RESolve-E, IER-Transmission and MECHanisms. The main reasons for selecting these five specific models and tools for the demonstration exercise were the fact that they appeared in the top combinations of WP3 and at the same time they were available to the project partners. In addition, the combination of these models and tools were expected to highlight:

a) The possibility of linking models that use different time resolutions,
b) The problems/advantages of linking overall energy system models with specialized models of the electricity system,
c) The possibility of linking techno-economic with behavioral models.

A brief introduction of the five models/tools is given below. Additional information can be found in Appendix I.

TIMES

TIMES is a technology rich bottom-up optimization model of the whole energy system. It has been applied to numerous energy systems. The version examined here is the Pan European TIMES model, which is a multi-regional model covering trade of energy commodities and GHG emissions among the EU member states. The model is extended to Switzerland, Norway and Iceland in the EU30 version, and to the Western Balkan countries in the PET36 version.

COMPETES

COMPETES is an EU-wide power sector model. The current static version is used to provide optimal unit dispatch in the various national power systems and more importantly power trade flows between countries, enhanced by the ability to spot congestion per connection, in terms of value and time. Moreover, it can explicitly provide insights about system load and RES curtailment.

Climate Bonus

Climate Bonus deviates from the traditional notion of models. It can be better described as an individual based CO_2 emissions calculator. It uses a highly detailed list of products and services consumed by individuals. By this, the model calculates CO2 emissions from the consumption of different products and service, while it has the advantage to aggregate the individual input/output into a database for further elaboration and also to provide comparative statistics. (Climate Bonus also provides individual-level feedback on carbon footprint and has thus even potential to influence consumer behavior. This might be important when trying to support energy system transitions in real-world contexts. This aspect was not specifically considered in the linking exercise of ATEsT WP5, however.)

RESolve-E

The model focuses exclusively on the RES part of the electricity system. It uses a highly detailed input of technical and financial attributes of RES technologies/projects and finally it can provide capacity and production projection per technology, cost developments and a full assessment of specific support measures.

IER-Transmission

IER-Transmission is a model that provides the optimal investment plan for both power generation and transmission, while an extension for storage is under development. It can also give a detailed indication of the total system cost. For the time being, the focus of the model lies on Germany by considering endogenously the electricity trade with the neighboring countries and Scandinavia. It is based on a high spatial resolution and contains a detailed list of power generation technologies.

MECHanisms

Mechanisms, is a tool rather than a model. It is focused mainly on energy efficiency projects/programs, where the major function is to guide and assist project managers through critical decisions involved in the development of the project. It is used for analyzing how to interpret certain social behaviors in various projects' frameworks.

3. Theoretical background of linking models

Coupling or linking models of different natures or purposes are considered by some specialists as a second best option when compared with the ideal one, i.e. a single model able to cast the desired level of detail in results based on a consistent and coherent mathematical formulation. On the other hand it might be impossible to have a single model able to answer all the relevant policy and research questions. In practice, some energy choices are determined by social preferences and parameters that are beyond economic modeling. Various models and tools may, however, provide valuable insights on specific issues in discussion even in this case. Models and tools can also affect the transparency of the process.

It is important to remember that the usefulness of models and tools should be defined from the users/decision-makers point of view, which also means that the usefulness varies depending on the real-world context.

The ideal model should be **technologically explicit**, **offer microeconomic realism** and **macroeconomic completeness** [1]. However, when computational resources have to be taken into account, model development faces the tradeoff between simplicity of model formulation and the level of detail preserved in the model, or in other words, some of the pillars that support the ideal model should be abandoned or answered insufficiently. For this reason, linear programming or data aggregated techniques survive in the competition among more sophisticated, disaggregated or more detailed models. They still keep the advantage of using large scale data, representing interdependencies in the system, and consequently they can provide critical insights without deviating from the main objective.

On the other hand, more detailed models that represent the interactions more realistically by introducing non-linearities fail in depicting the overall picture but succeed in approaching closer to optimality in a closer field of interest. Somewhere in the middle stands the coupling of models which reduces the aforementioned tradeoffs. The basic idea of coupling lies in dividing the whole system to study in subsystems, and allowing feedbacks to take place between them. There have been methods to realize the coupling that request the change of the mathematical formulation of existing modes (e.g. MCP, game theoretic approaches) while others that keep the models as such but create a new interconnector model able, under certain assumptions, to link them in an optimal way (e.g. oracle based optimization method [4]).

Serious research efforts have been devoted in combining bottom-up technology-rich models with general equilibrium models in a coherent and consistent mathematical formulation, so that the existence and the uniqueness of equilibrium are guaranteed. For instance, in [2] a unifying framework is provided under an MCP format for bottom-up and top-down models. However significant challenges arise when dimensionality issues have to be considered, especially if flexibility in imposing various constraints is required by the modeler.

Similar attempts have been made to bring together energy system models (bottom-up) with MGM[1], as in [3], where hard-linking and soft linking approaches have been investigated. This perspective, when it is examined properly – with scientific rigidity (hard link approach), offers the advantage of preserving both the energy and the capital markets in equilibrium. Hence the framework for the analysis of the investment in the energy sector becomes by far more complete.

A soft linking approach offers a more detailed representation but fails to address the simultaneous equilibria in both markets. On average, on the front of linking economy rich and technology rich models there exists a satisfactory literature to rely on ([1], [2], [3], [6]). However, scientific articles that describe linking of more than two different types of models via soft or hard techniques still are very scarce. However,

[1] Macroeconomic Growth Model

scientific efforts for the linking of energy systems models with specific climate models as in [4] seem very promising and robust, especially since they offer a general framework, which can be extended for the linking of models with greater heterogeneity.

The time resolution used in model can be quite different, depending on the specific focus on the model. For instance a systemic model can have a time horizon of 50 years, and time steps of five years producing results on an annual basis. A model focusing on RES electricity curtailment calculation will need at least hourly data and will produce results in the same resolution. A model focusing on grid issues will focus on specific instances of the grid operation. It is obvious from the above that exchanging information between models with such varying time resolutions can be a challenge. The issues of convergence and stability of the linking process of heterogeneous model are not simple either. An attempt of introducing convergence criteria is presented in section 4, but stability issues cannot be foreseen at this point. Finally, the list of issues presented here is not exhaustive, and the linking of diversified and multiple models can lead to issues that were not addressed up to know.

4. Linking Scheme

Using the rationale of model linking described above, a linking scheme is built for the models presented in Section 2. Some of the models are run on an EU level, while others apply on a national scale. The models use different time scales for the analysis, i.e. hour, year or multiyear. As a result, all the data have to be formed so as to fit adequately to each model. Moreover the issue of how to synchronize independent model runs will be raised here, especially when the models have to exchange information between them. This topic will not be addressed in detail, but general principles which have to be followed will be provided.

Most of the models have a significant amount of common input data. So, we have assumed a common database from which the models extract their inputs. The advantage of having a common database (see Table 1) covers the need for maximum possible data consistency. This database should include all the necessary data at the highest available geographical granularity and time scale, in order to allow the extraction of data at the level desired by each model. The rest of the data input for each model is assumed to be stored in independent, dedicated databases. More information on the specific independent databases for each model can be found in the report of WP4, available of the ATEsT project webpage.

Using these background assumptions, the linking scheme presented in Figure 1 is proposed. The example in Figure 1 is more of a sketch than a definite and robust proposal on how to design the linking model procedures. This is mainly because the number and the characteristics of the selected models are quite diverse, and sufficient knowledge of the models by the project team cannot be fully exploited in the absence of an extensive application to numerous test cases.

The basic output of the linking scheme comes from TIMES which is the only energy system model available in the group of models examined. The remaining models focus on specific areas: three of them (RESOLVE-E, COMPETES, IER-Transmission) are models strongly related to aspects of the electricity system, while the other two are more behavior-oriented (Climate Bonus relates to individual- and aggregated-level consumer behavior and MECHANISMS for interpretation of behavioral issues in specific project contexts). Therefore, we firstly address linkages between RESOLVE-E and COMPETES, and in parallel the model IER-Transmission; the outputs of these three models refine the power sector attributes that are used as an input to the TIMES model (see Figure 1).

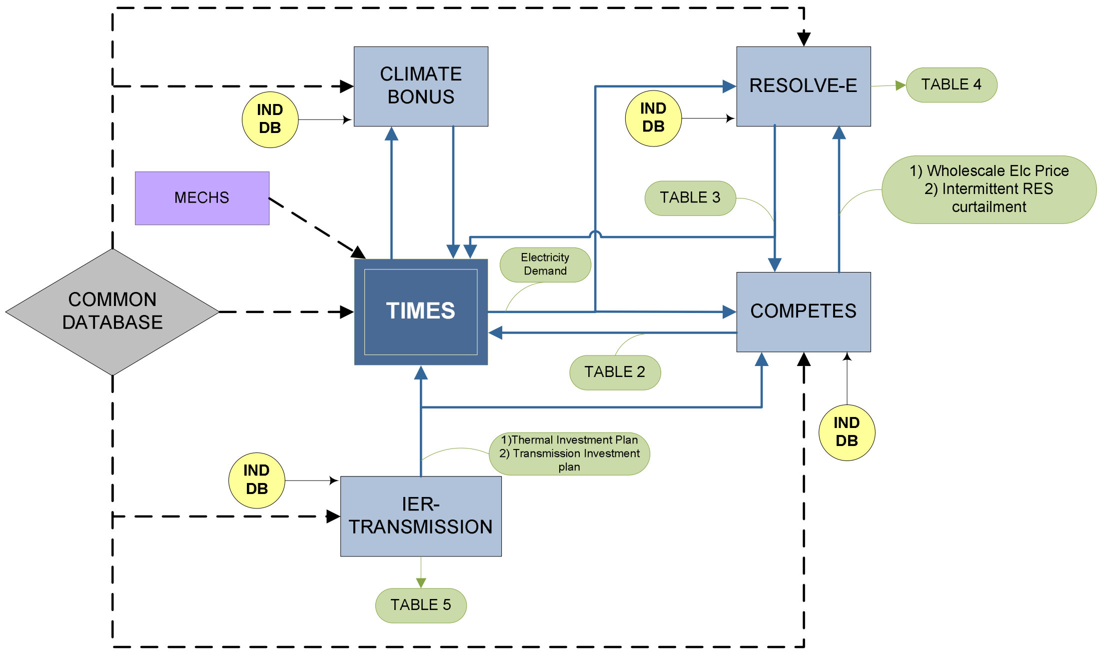


Figure 1: Schematic of the model linking proposal

More specifically, the linking scheme could follow the steps below:

Step 1:

The systemic model TIMES is run having input from a CGE model (in order to calculate future useful energy demand) and Climate Bonus (Figure 2).

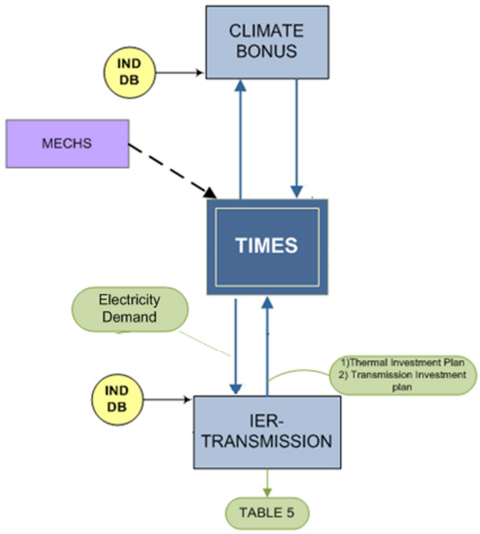


Figure 2: Step 1 of the linking procedure

CLIMATE-BONUS provides enhanced CO_2 emission data for the consumption sectors. The model can calculate CO_2 emissions per energy use, based on detailed data of technologies and behavior. It can therefore provide more accurate coefficients that can be used in a systemic model like TIMES, enhancing in this way the representation of GHG emissions that are not dependent only on technologies but also on behavioural aspects. Furthermore, the selection of a representative sample of the Climate Bonus database can be used as a reliable basis for the calculation of consumer elasticities related to the price or quantity of CO_2.

Using the results of the application of MECHanisms, in a large number of cases/projects, important information may be obtained regarding typical social behaviors in various energy efficiency programs/projects. Such kind of information provides an opportunity of quantifying different modes of social involvement, especially when compared to BAU conditions, and critical insight can be gained, especially on the modeling of social behavior. This is the kind of input that MECHanisms will provide to TIMES. Nevertheless, testing these assumptions on real case studies is considered crucial for determining the connections between MECHANISMS and the other models.

The electricity demand from TIMES is used as an input to IER-Transimission. IER-Transmission also uses other input from its own independent database and the common database, while the output of the model (thermal power investment plan, and power transmission investment plan) feeds TIMES, in the form of forced investment scenarios. The largest part of the output of IER-Transmission is stored in Table 5 and doesn't interact with the rest of the models.

Step 2:

The electricity demand provided by TIMES is used as an input to the iteration between RESolve-E and COMPETES (which focus on the power sector and renewables in particular). The thermal power system and transmission is optimized by IER-Transmission (Figure 3).

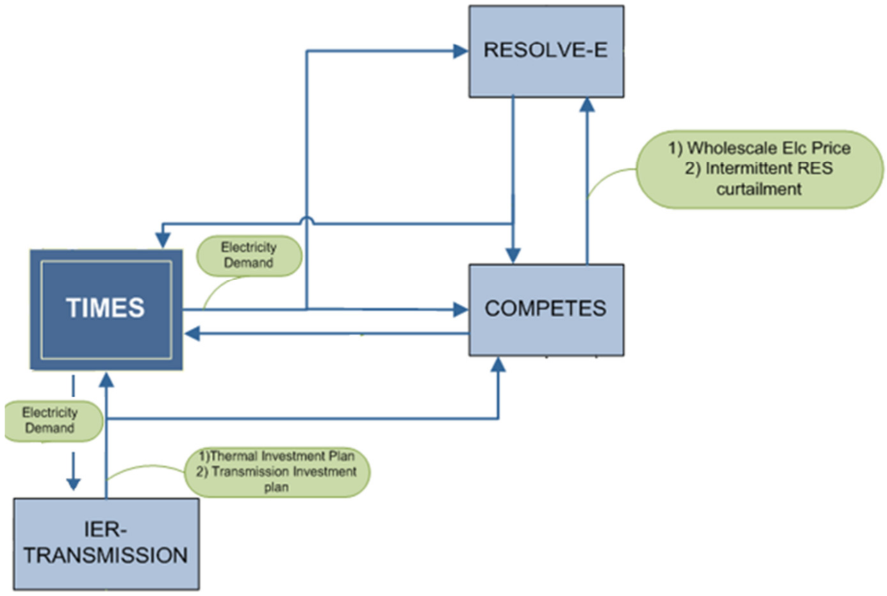


Figure 3: Step 2 of the linking procedure

According to the depicted scheme, RESolve-E and COMPETES will be used to fine tune the operation of the power sector. Both these models have been developed at ECN, and they are coupled in the framework of WINDSPEED project [5]. Based on this experience, it was attempted to extend further this coupling framework inside the linking scheme presented here.

TIMES which as an energy system model represents endogenously the competition between the different energy carriers (natural, gas, oil electricity, etc) and therefore provides the final electricity demand to RESolve-E & COMPETES. For RESolve-E, the annual final electricity demand is a direct input, but in COMPETES further analysis of the annual final electricity demand is needed. It is necessary to transform the annual final electricity demand to an hourly pattern, since in COMPETES an hourly simulation is conducted. In the TIMES models, the representation of time is as follows: first of all there is the possibility to split the time horizon of the study in 1,2,…,5 or more years, dividing it in certain periods. Then each year can be split in time slices, i.e. representative instances of the whole year, the synthesis of which provide the annual picture. A number of 12 time slices is rather common, constructed by the Cartesian product of two sets, Season= {Winter, Spring, Summer, Autumn} and Load_Level = {Day, Night, Peak}. The second set is used to replicate the daily chronological load curve, i.e. the low levels of electricity demand at night, the peaks in electricity demand during the day, and the moderate load levels observed the rest of the day. It is important to note that this split is not fixed and can be formulated according to each modeler's judgment. With these in mind, the hourly pattern needed by COMPETES can be obtained by transforming the seasonal stepwise functions taken from TIMES into non-linear ones that will imitate seasonal load curve patterns (Figure 4).

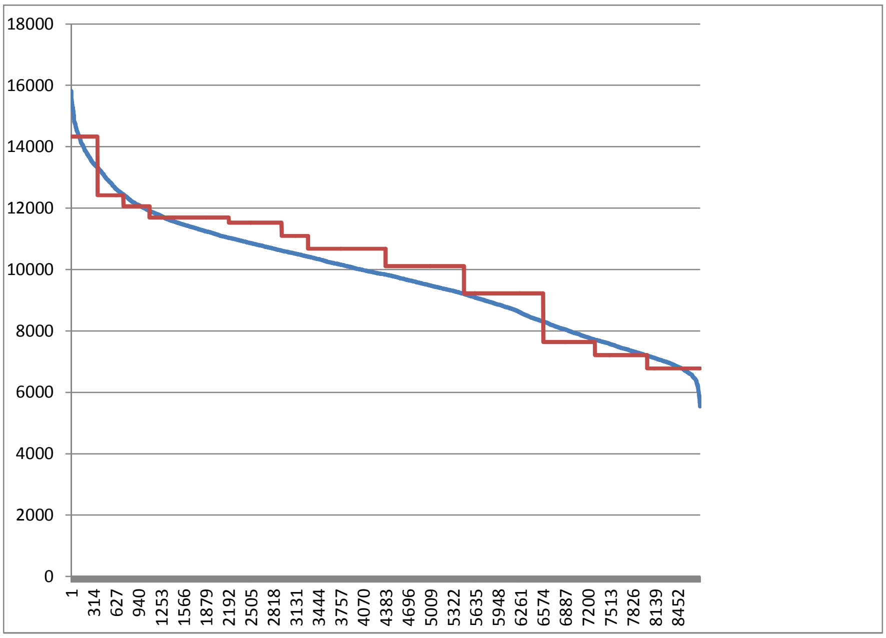


Figure 4: Deriving an hourly load curve (blue line) from the stepwise approach used in TIMES (red line).

Having described the process of how TIMES output (final electricity demand) will feed RESolve-E and COMPETES, we can move on presenting the coupling between these two models (Figure 5). In the coupling approach that is proposed, RESolve-E is run first.
RESolve-E requires as driver-input the wholesale electricity price, and during the first run of RESolve-E, the marginal price of electricity derived with TIMES can be used. The other basic inputs required for the first run of RESolve-E, coming either from the independent (IDB) or the common database (CDB), are support schemes for RES capacity development (IDB), fuel prices (CDB) and technical and economic characteristics of RES technologies. It is important to note at this point that RESOLVE-E has to be properly calibrated with the relevant historical data of RES capacity expansion before running the model.

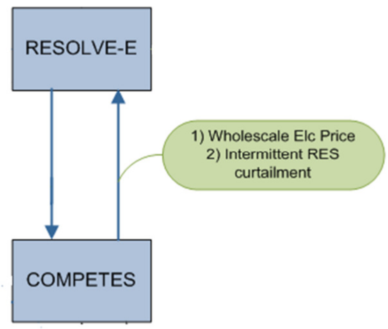


Figure 5: Iteration between RESolve-E and COMPETES

Once the first run of RESolve-E is finished, COMPETES can be run using the RES capacity development and RES electricity production taken from RESolve-E, the final electricity demand taken from TIMES, the thermal generation investment plant and the transmission investment plan taken from TIMES, shaped by the output of IER-Transmission. IER Transmission has been chosen for this role because it is formulated to optimize both generation and transmission capacity expansion simultaneously. Furthermore as one is approaching 2050, the role of thermal generation is highly transformed to complement RES electricity production. This transformation will be highly proportional to the lowering of the average cost of RES production, the appearance of commercial storage technologies and the high levels of CO_2 emission costs.

The robust calculation of the wholesale electricity price from COMPETES is used as an input to the second run of RESolve-E. This new price is much more reliable, since it is calculated from an hourly simulation, taking into account operational issues like ramp up/down constraints, unit-commitment complexity as well as transmission constraints and the relevant congestion implications. Another important output of COMPETES which will be used as an input to RESolve-E is the expected load curtailment and RES production curtailment due to RES production intermittency and grid constraints. It is highly probable that if the curtailment levels are above a certain threshold, then the RES capacity development calculated by RESolve-E will be affected. A new RES capacity development scheme calculated by RESolve-E will feed COMPETES and sequentially a new wholesale electricity price and RES curtailment from COMPETES will feed RESolve-E. When this iteration process will not change the RES capacity development more than a certain percentage (5%) then it can be terminated. The final results will come from RESolve-E, where it is necessary to correct the RES production according to the curtailment levels given by COMPETES.

Step 3:

Once the iteration process in Step 2 is terminated, the outputs of RESolve-E and COMPETES will be used in the other models of the linking scheme (Figure 3). The remaining input data come from the common database and an independent specialized database. Table 2 presents the major output of the COMPETES model which will be used as input to the TIMES model. A series of the most important information that will shape the power subsector of TIMES are included in this table. These include the RES capacity development and RES electricity production, RES electricity curtailment, power trade flows and congestion prices (the marginal price of the transmission capacity). With these updated inputs TIMES is run again, providing an update of the development of the overall energy system and of the electricity demand.

A convergence scheme is required for this process, which is necessary since the iteration between the model runs will result to a shift of the optimal points in each model. In order to deal with this we need to define a kind of “confidence intervals” between some key exchange variables. One such key variable is the final electricity demand. TIMES provides the final electricity demand to RESOLVE-E, COMPETES and IER-Transmission, and RESOLVE-E returns cost development indications about renewable technologies while COMPETES provides the wholesale electricity price to RESOLVE-E and IER-Transmission provides the thermal power and transmission grid development. This iteration will converge when $\frac{\sum_{j=1}^{N} Q_{i+j}}{N} - Q_i \leq \varepsilon$, where Q_l is the final electricity demand in the i-th iteration of the TIMES and e is the user specified confidence interval. It is highly probable that for the interaction scheme of Figure 1, more sophisticated convergence rules are required, but these can be derived only during the process of actually linking the models. The optimality of the solution in such an iteration is not guaranteed, and it should be closely monitored and empirically verified. The convergence of the results of the different models for the same variables (e.g. power flow calculated from IER-Transmission and COMPETES converging to the same value) is an additional sign that the linking process approaches a common solution.

Table 1: Basic content of the Common Database

COMMON DATABASE				
	Input Parameter Name	**Input Parameter Description**	**Units**	**MODELS**
	e.g.			1: TIMES, 2:IER-TRANSMISSION, 3: COMPETES, 4: RESOLVE-E, 5: CLIMATE-BONUS
GENERAL	TS	Split of the year in time segments	%(fraction of year)	1,
	Discount	Discount factor for the computation of the NPV	%	1,
REGIONS	Inter_Cap	Interconnection capacity between regions	Unit of capacity	1,3,
SECTORS	Energy balance	Table of the energy balance of a country	Unit of energy	1,
	Fuel_prices + CO2 price	Fuel prices per sector and energy carrier	m€/PJ	1,2,3,4,
	Import_prices	Import prices per energy carrier	m€/PJ	1,
	Export prices	Export prices per energy carrier	m€/PJ	1,
	Demand_sec_ts	Split of demand for useful energy per sector and time segment	PJ	1,
DEMANDS	*Demand drivers*			1,
	GDP	Gross domestic product	m€	1,
	GDP growth	Growth of GDP	%	1,
	Value_added	Value_added per sector	m€	1,
	IPI	Industry production index per (sub)sector	Units produced	1,
	Population			1,
		Socio-professional classes of households		1,
		Budget share for Energy goods and services		1,
	Number of persons per household			1,
	Demand_evol	Evolution of demand per (sub)sector and end-use	PJ	1,
TECHNOLOGIES	Life	Technical lifetime of investment	Years	1,
	AF	Availability factor of technology(annual or seasonal)	%	1,3,
	INVCOST	Investment cost per technology	€/(unit of installed capacity)	1,2,4,
	Upper limit	Upper limit of technology penetration or upper limit of activity of a technology	% or absolute	1,
	Lower limit	Lower limit of technology penetration or upper limit of activity of a technology	% or absolute	1,
	Fixed limit	Fixed limit of technology penetration or fixed limit of activity of a technology	% or absolute	1,
	Eff	Efficiency of technology	%	1,3,
	E_stock	Existing stock per technology	Unit of installed capacity	1,

	CF	Capacity factor per technology(obligatory only for end-use demand technologies)	%	1,
	FIXOM	Fixed operation and maintenance cost per technology	€/unit of capacity	1,4
	VAROM	Variable operation and maintenance cost per technology	€/unit of energy	1,3,4,
	Startyr	The starting year that an investment in a technology can be done		1,
	RESID	Evolution of retirements per technology	Unit of capacity	1,3,
	REH	Ratio electricity to HEAT for CHP technologies	%	1,
Technological progress	LR	Learning rates		1,
	R&D	R&D cost if exogenous investment		1,
Emission	Emission factors	GHG Emission factors per fuel or technology		1,2,3,
Resource use Constraints		Geological constraints Political constraints		1,
Resource use Incentives		Feed-in tariffs Subsidies Sale obligations or other mechanisms which might alter the Merit Order Curve		1,
POSRES, NEGRES	Reserve requirement	Reserve requirement	Unit of Power (MW	2,1,

Table 2: Output of the COMPETES model which will be used as input to the TIMES

TABLE 2		
Output Parameter Name	**Output Parameter Description**	**Units**
Generation	Generation per technology per country for selected period in a year	Gwh
Net Imports/Exports	Net import/exports per country for selected period in a year	Gwh
Demand curtailment	Curtailment of demand per country for selected period in a year due to transmission constraints	Gwh
Intermittent RES curtailment	Curtailment of intermittent RES (e.g., wind) per country for selected period in a year due to transmission constraints	Gwh
Flows	Power Trade flows between countries	Gwh
Congestion	% fraction of time congestion occurs per line in a year	
Emissions	CO2 Emissions per country	t CO2e
Congestion price	Marginal Value of the transmission capacity (shadow price)	€/MWh

Table 3: Output of RESOLVE-e that is used as an input to TIMES and COMPETES

TABLE 3		
Output Parameter Name	**Output Parameter Description**	**Units**
RES-E projection	Projection of RES-E developments, capacity and production. Can be expressed per country,technology,band,year or any sum over these sets.	MW and GWh
Biomass resource mix	Projection of biomass utilization per feedstock category. Can be expressed per country,technology,year or any sum over these sets.	GWh_e and GJ_{input}
Cost developments	Development of several cost (investment costs, O&M costs, levelized production costs). Can be expressed per country,technology,band,year.	€/kW, €/kWh

Table 4: Output of RESOLVE-E that doesn't interact with the other models.

TABLE 4		
Output Parameter Name	**Output Parameter Description**	**Units**
Total additional costs	Total additional costs wrt whole sale electricity price. Can be expressed per country,technology,band,year or any sum over these sets.	€ or €ct/kWh
Utilization of specific support measures	Utilization of a specific RES-E support measure	GWh_e
Cost effectiveness of support measures	Average additional costs per kWh for a support measure	€ct/kWh
Realization effectiveness of support measures	Realized RES-E production per measure. Has more value if compared with alternative measures	GWh
TradeFlows	Trade of green certificates between countries	GWh/yr

Table 5: Output of IER-Transmission that doesn't interact with the other models.

TABLE 5		
Output Parameter Name	**Output Parameter Description**	**Units**
System cost	Detailed Discounted total cost of the optimal system	€'(base year)
Energy balance	Injection/withdrawl at each node	MW
	Power station output at each node	MW
Power station	Fuel consumption of each power station	MWh
	Emissions of each power station	Ton CO2
Powerflows	Power flow on each line during each period	MW

Table 6: Individual Database for the input of RESOLVE-E.

IND DB (RESOLVE-E)			
Categories	**Input Parameter Name**	**Input Parameter Description**	**Units**
GENERAL	Taxrate	corporation tax	%
	InflationRate	EUROSTAT definition of inflation	%
REGIONS	Inclusion	Indicate if and from which year on countries can share their potentials and RES-E targets	
SECTORS	-	-	-
TECHNOLOGIES	ExclusionOutput	Exclusion of a certain country,technology,band combination from the model	
	Realisations	Statistical RES-E production per technology,country,year	GWh_e
	LeadTime	Lead time of a technology	years
	PipelineSucceed	Factor needed to calculate how much of the realistic potentials is really looked at by investors/potentially in the pipeline	%
	Intermittence penance	Intermittence penalty per country,technology	$€ct/kWh_e$
	Debt share	Debt share of the investment	%
	Debt rate	Debt rate of the investment	%
	MinRoE	Minimum Return on Equity	%
	LoanPeriod	Duration of the loan	%
	Full load hrs	Yearly full load hours of a technology	hrs/yr

	Input value	Main factor determining the realistic potential per country,technology,band in 2040	Unit differs per technology.
	Value conversion factor Input	Conversion factors to come level by level from the main factor of the realistic potential to the final realistic potential in GWh	Unit differs per technology and per assessment level
	STD electricity commodity price	Relative standard deviation in the electricity price, used for calculation of risk premium	
	Production volume STD	Relative standard deviation in the yearly production of variable technologies, used for calculation of risk premium	
	Fuel costs STD	Relative standard deviation in biomass feedstock prices, used for calculation of risk premium	
	Investment STD	Relative standard deviation in investment costs, used for calculation of risk premium	
	O&M fixed STD	Relative standard deviation in fixed O&M costs, used for calculation of risk premium	
	O&M var STD	Relative standard deviation in variable O&M costs, used for calculation of risk premium	
Technological progress	Progress Ratio	Progress ratios	
Policies	*Several*	The following kind of support policies are possible: -Feed in tariff -Feed in premium -Fixed premium -Bidding systems -Quota obligations -Investment subsidies -4 types of financials incentives	

Table 6: Individual Database for the input data of **COMPETES**

IND DB (COMPETES)			
	Input Parameter Name	**Input Parameter Description**	**Units**
GENERAL	Include/exclude loop flow_based network	User-defined parameter to simulate flow-based market coupling or not	
REGIONS AND INTERCONNECTIONS	NTC	Trading capacity between countries in both directions	MW
	T_up and T_down	Physical interconnection capacity between countries in both directions (T_up is the limit for the direction as the flow, T_down is the opposite direction)	MW
	Susceptance (Optional)	Susceptance of an ACline between countries if flow-based market coupling is simulated	1/ohms
TECHNOLOGIES	Must_run generation	Must_run generation per technology per country (inflexible generation)	MW
	Loadfactorwon	Hourly load factor time series of wind onshore (availability of wind per hour per country)	
	Loadfactorwoff	Hourly load factor time series of wind offshore (availability of wind per hour per country)	
	Loadfactorsunpv	Hourly load factor time series of sun pv (availability of sun per hour per country)	

	Ror	Run of river share of hydro generation per month per country	

Table 7: Individual Database for the input data of **IER TRANSMISSION**

IND DB (IER TRANSMISSION)				
	Input Parameter Name	**Input Parameter Description**	**Units**	**Comments**
GENERAL	PREF	Reference Active Power	Value in MVA	
	TRM	Transmission reliability margin	Percentage of total transmission capacity	
	Resstartlevel	Initial level of water reservoirs	% of total reservoir fill level	
Power stations	Generation capacity	Maximal power output	Unit of Power / MW	
	Minimal power output	Minimal power output required for stable operation of power plant	Unit of Power / MW	
	EFFOPT	Efficiency at maximal power output	percentage	To harmonize with Common Database
	EffMin	Efficiency at minimal power output	Percentage	
	Fueltype	Used Fuel for electricity generation	Number	
Transmission lines	Start	Starting point of line	Binary (1=yes/0=no)	
	End	Terminal point of the line	Binary (1=yes/0=no)	
	Resistance	Resistance	Unit of Resistance / Ohm	To harmonize with COMPETES IND DB
	Reactance	Reactance	Unit of Resistance / Ohm	
	Limit	Maximal power flow on line	Unit of Power / MW	
	Voltage	Level of Voltage	Unit of voltage / V	
Pump storages	Storage_Vol	Maximal level of water reservoir	Unit of Energy / MWH	
	Pumpcap	Pumping capacity	Unit of Power / MW	

5. Conclusions

A proposed linking scheme was presented showing possible interactions between models that focus on different parts of the energy system and use different methodologies. It was not possible to perform an actual linking exercise, since an extension of some of the models is necessary to cover the whole of the EU. This exercise should be performed in the future in order to examine the issues raised in the previous section as well as the convergence and optimality behavior of the combination of models.

In the linking scheme proposed by the ATEsT project, a CGE or MGM model is not included. The reason for this is, as described in Sections 2 and 3, that this work has been already performed successfully in the past. It is important to note at this point that efforts of hard linking more than two models are rare, most likely due to issues highlighted in the Section 3, regarding the time and spatial resolution of the models, their ownership (among the exceptions is the UKERC 2050 Scenarios). The participation in the linking scheme of other models, such as agent based models or models that focus on reproducing behaviours of agents in the energy system under the principles of the game theory, should be examined as well. In this case the linking would become even more demanding, and this option should be investigated thoroughly in future research.

Finally, one of the main conclusions of the analysis of WP4 and WP5, is the fact that a common database is necessary, to ensure a consistent input to all models.

6. References

[1] Hourcade, J.-C., Jaccard, M., Bataille, C., Gershi, F. (2006). Hybrid modeling: new answers to old challenges. Energy Journal-Special Issue 1–12.

[2] Böhringer, Christoph and Rutherford, Thomas F. (2006). Combining Top-Down and Bottom-Up in Energy Policy Analysis: A Decomposition Approach. ZEW - Centre for European Economic Research Discussion Paper No. 06-007. Available at SSRN: http://ssrn.com/abstract=878433 or http://dx.doi.org/10.2139/ssrn.878433.

[3] Bauer, N., Edenhofer, O., Kypreos, S., (2008). Linking Energy System and Macroeconomic Growth Models. Journal of Computational Management Science (Special Issue on Managing Energy and the Environment) 5(1-2), 95-117.

[4] F. Babonneau, C. Beltran, A. Haurie, C. Tadonki, J.-P. Vial (2007). Proximal-ACCPM: a versatile oracle based optimization method. Optimisation, Econometric and Financial Analysi, Advances in Computational Management Science, Volume 9, Part I, 67-89, DOI: 10.1007/3-540-36626-1_4.

[5] L. Cameron, J. van Stralen, K. Veum (2011). Scenarios for offshore wind including spatial interactions and grid issues. ECN, Report D6.1 WINDSPEED project, IEE/07/759/S12.499460.

[6] Capros P., Koyvaritakis N., Paroussos L., Karkatsoylis P.,Fragkiadakis K., Van Regemorter D., Zaporozhets V., Gharbi Q., Le Mouel P., Delkis K. (2010). “Description of GEM-E3 Model Improvements”, Report of FP6 Project No 044089 MODELS, available at: http://www.ecmodels.eu/index_files/MODELS%20Description%20of%20GEM-E3%20Developments.pdf

Appendix I: Model Description

PanEuropean TIMES

COMPETES

Climate Bonus

RESOLVE-E

IER Transmission model

MECHanisms

PanEuropean TIMES.

<u>Model Input Requirements and Model Output Results</u>

A. **Model description. Detailed list:**
    a. Regions covered by the model.
        i. All EU countries – level of detail: National
    b. Sectors and subsectors covered by the model.
        i. Residential
        ii. Commercial
        iii. Agriculture
        iv. Industry
        v. Power sector
        vi. Transport
        vii. Transformation sector (refineries, gas liquefaction-gasification, coke oven, coal-briquettes, Biofuels)
    c. Primary Energy sources covered by the model (as detailed as possible).
        i. Coal and coal byproducts (hardcoal, brown coal, coke, lignite, coke oven gas, Blast-Furnace gas)
        ii. Oil products (crude oil, gasoline, kerosene, naphtha, diesel, LPG, Refinery Gas, HFO, oil feedstocks, non-energy petroleum products, other petroleum products)
        iii. Natural gas
        iv. Gasworks gas
        v. Wood
        vi. Biogas
        vii. Biofuels
        viii. Waste (municipal, industrial)
        ix. Geothermal energy
        x. Wind energy
        xi. Solar energy
        xii. Hydraulic energy
    d. Demands covered by the model.
        i. Residential – Commercial sector
            1. Space Heating
            2. Space Cooling
            3. Water heating
            4. Lighting
            5. Public lighting
            6. Cooking
            7. Refrigeration

        8. Cloth washing
        9. Cloth drying
        10. Dish washing
        11. other electric
        12. other energy
    ii. Agriculture generic demand
    iii. Industry
        1. Iron and steel
        2. Nonferrous metal
        3. Chemical
        4. Nonmetallic mineral products
        5. Food, drink & tobacco
            a. Generic demands of Process Heat, Steam and Machine drive.
        6. Textile, leather & clothing
            a. Generic demands of Process Heat, Steam and Machine drive.
        7. Paper and printing
        8. Engineering and other metal
            a. Generic demands of Process Heat, Steam and Machine drive.
        9. Other non-classified
            a. Generic demands of Process Heat, Steam and Machine drive.

e. Drivers used by the model
    1. GDP - rate of change
    2. Available income – rate of change
    3. Population – rate of change
    4. Value added for industrial sectors

f. Technologies covered by the model.
    i. Power Sector
        1. Electric Power
            a. Natural Gas Combined Cycle
            b. Gas Turbine (peak)
            c. Natural Gas CCS
            d. Fuel cell with Natural Gas
            e. Coal Steam Turbine
            f. Coal IGCC
            g. IGCC CCS

h. Steam Turbine HFO
i. Diesel Turbine(peak)
j. Nuclear 3rd generation
k. Nuclear 4th generation
l. Fuel Cell Hydrogen
m. Wind onshore
n. wind offshore
o. PV roof panel
p. PV plant
q. Solar thermal plant
r. Geothermal Hot dry rock
s. Geothermal Steam Turbine
t. Small - hydro run of river
u. Hydro lake
v. Hydro Pump Storage
w. Fuel Cell Biogas
x. Ocean power wave energy converter
y. Tidal Stream Generator

2. CHP – Cogeneration Power plants – Autoproducers
    a. Gas combined cycle
    b. Gas combined cycle CCS
    c. Coal steam turbine (condensing)
    d. Coal IGCC CCS
    e. Gas combined cycle backpressure
    f. Coal combined cycle backpressure
    g. Biomass steam turbine
    h. Biomass IGCC
    i. Gas Fuel Cell
    j. Biogas Fuel Cell
    k. Gas internal combustion engine
    l. Biogas internal combustion engine
    m. Municipal Sludge Steam turbine
    n. Recovery Boiler black liquor Pulp&Paper Heat
    o. HFO combined cycle

ii. Heat Plants
1. Gas district heating
2. Oil district heating
3. Coal district heating

iii. Transport
1. Large/Small cars
    a. Gasoline

b. Diesel
c. Bio FT-diesel/Fossil FT-diesel
d. Biodiesel
e. Ethanol
f. LPG
g. Natural gas/biogas
h. Methanol
i. Hybrid gasoline-ethanol
j. Hybrid diesel- bio FT diesel – Fossil FT diesel – biodiesel
k. Electric
l. Hydrogen Cars

2. Bus Intercity/Bus urban
    a. Diesel
    b. Gasoline
    c. Ethanol
    d. Natural gas/biogas
    e. Methanol
    f. Biodiesel
    g. Hydrogen
3. Trucks Medium Duty / Heavy Duty
    a. Diesel
    b. Hybrid diesel – bio FT diesel – Fossil FT diesel – biodiesel
    c. Hybrid gasoline-ethanol
    d. Biodiesel
    e. Ethanol
    f. Natural gas/biogas
    g. Methanol
    h. Hydrogen
4. Motorbikes
    a. Electric
    b. Gasoline
    c. Gasoline-ethanol
5. Infrastructure Technologies for fuel transportation

iv. Industry
1. Crude aluminium production(9 different technologies)
2. Ammonia production(5 different technologies)
3. Other chemicals (27 different technologies)
4. Chlorine production (3 different technologies)
5. Cement demand (5 different technologies)_

6. Secondary copper production(3 different technologies)
7. Glass Flat demand(2 different technologies)
8. Hollow glass production (4 different technologies)
9. Raw iron and crude steel production (17 different technologies)
10. Clinker kilns(8 different technologies)
11. Other non ferrous metals (26 different technologies)
12. Other non-metallic minerals (26 different technologies)
13. Other industries (26 different technologies)0
14. Pulp production (15 different technologies)

v. Supply
   1. Gasification(5 technologies – production of DME/FT-diesel/methane/methanol/hydrogen from black liquor)
   2. Gasification(4 technologies – production of DME/FT-diesel/methane/methanol/hydrogen from coal)
   3. Gasification of biomass to methane
   4. Decomposition of biowaste/crop for biogas to methane(biogas)
   5. Synthesis(4 technologies – production of DME/FT-diesel/methane/methanol/hydrogen from natural gas)
   6. Fermentation, crops(wheat) to ethanol
   7. Transesterification of vegetable oils
   8. Vegetable oil extraction
   9. Ethanol production from sugar/starch crops
   10. FT-diesel production from woody biomass
   11. Ethanol production from woody biomass
   12. Methanol production from woody biomass
   13. DME production from woody biomass
   14. Rape seed production
   15. Starch crop production
   16. Sugar crop production
   17. Grassy crop production
   18. Woody crop production
   19. Collection of agricultural waste
   20. Collection of forestry residues
   21. Collection of wood processing residues
   22. Hydrogen production (11 technologies)
   23. Hydrogen liquefaction
   24. Hydrogen production + coal gasification

vi. Storage and transportation technologies
   1. Removal by enhanced oil recovery

2. Removal by depleted oil fields(offshore/onshore)
3. Removal by depleted gas fields
4. Removal by enhanced coalbed methane recovery
5. Removal by deep saline aquifiers
6. Mineralization for CO2 storage
7. Removal by afforestation

B. Model/Tools data input

	Input Parameter Name	**Input Parameter Description**	**Units**
	e.g.		
GENERAL	TS	Split of the year in time segments	%(fraction of year)
	discount	Discount factor for the computation of the NPV	%
REGIONS	Inter_Cap	Interconnection capacity between regions	Unit of capacity
SECTORS	Energy balance	Table of the energy balance of a country	Unit of energy
	Fuel_prices	Fuel prices per sector and energy carrier	m€/PJ
	Import_prices	Import prices per energy carrier	m€/PJ
	Export prices	Export prices per energy carrier	m€/PJ
	Demand_sec_ts	Split of demand for useful energy per sector and time segment	PJ
DEMANDS	*Demand drivers*		
	GDP	Gross domestic product	m€
	GDP growth	Growth of GDP	%
	Value_added	Value_added per sector	m€
	IPI	Industry production index per (sub)sector	Units produced
	Population		
		Socio-professional classes of households	
		Budget share for Energy goods and services	
	Number of persons per household		
	Demand_evol	Evolution of demand per (sub)sector and end-use	PJ
TECHNOLOGIES	Life	Technical lifetime of investment	Years
	AF	Availability factor of technology(annual or seasonal)	%
	INVCOST	Investment cost per technology	€/(unit of installed capacity)
	Upper limit	Upper limit of technology penetration or upper limit of activity of a technology	% or absolute
	Lower limit	Lower limit of technology penetration or upper limit of activity of a technology	% or absolute
	Fixed limit	Fixed limit of technology penetration or fixed limit of activity of a technology	% or absolute
	Eff	Efficiency of technology	%
	E_stock	Existing stock per technology	Unit of installed capacity
	CF	Capacity factor per	%

		technology(obligatory only for end-use demand technologies)	
	FIXOM	Fixed operation and maintenance cost per technology	€/unit of capacity
	VAROM	Variable operation and maintenance cost per technology	€/unit of energy
	startyr	The starting year that an investment in a technology can be done	
	RESID	Evolution of retirements per technology	Unit of capacity
	REH	Ratio electricity to HEAT for CHP technologies	%
Technological progress	LR	Learning rates	
	R&D	R&D cost if exogenous investment	
Emission	Emission factors	GHG Emission factors per fuel or technology	
Resource use Constraints		Geological constraints Political constraints	
Resource use Incentives		Feed-in tariffs Subsidies Sale obligations or other mechanisms which might alter the Merit Order Curve	

C. Model output

Output Parameter Name	**Output Parameter Description**	**Units**
e.g.		
System cost	Detailed Discounted total cost of the optimal system expansion (e.g. per sector fuel expenditure, variable and fixed O&M costs, investment expenditures both in demand and supply, transportation or delivery costs) Graph with the transitional path , e.g. the cost as % of the GDP	€'(base year)
Energy balance	Energy balances per period of the study horizon	PJ
Some of which:		
	Primary energy	PJ
	Final energy per sector and energy carrier	PJ
	imports	PJ
	exports	PJ
	Emissions per sector/demand	Measurement unit of GHG
Optimal Investment plan	Installed Capacity of technology for each period of the study	Units of installed capacity
	To distinguish between Old and New Installed Capacity	
	Location of R&D investment	
Trade flows	Energy Trade flows between regions	PJ
Grid Infrastructure		
Emissions		t CO2e
Energy security indicators	From the overall system perspective (energy independency evolution) From grid perspective (supply outages)	
Benefits	Economic (in terms of GDP or energy savings) Social (welfare if measured) Environmental	

D. Answers to a Policy Question

The model was ranked among the top in answering the ATEsT trail policy question[s] in combination with other models:

1. How to achieve a low cost and low emissions energy mix ?

4. Which are the most competitive low carbon technologies in the medium and long term ?

5. Where should new energy installations be best located ?

6. In which R&D areas should a country invest ?

7. How should a country develop energy interconnections with other European and non European countries ?

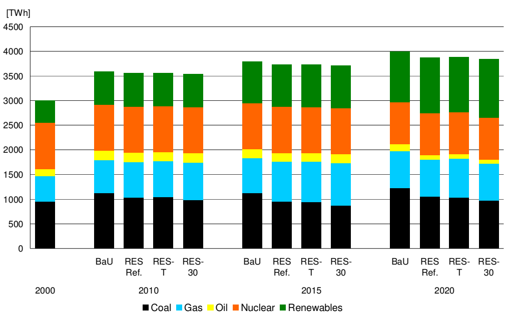
8. How to improve energy efficiency ?

A brief description on how the model may contribute to answering these policy questions follows:

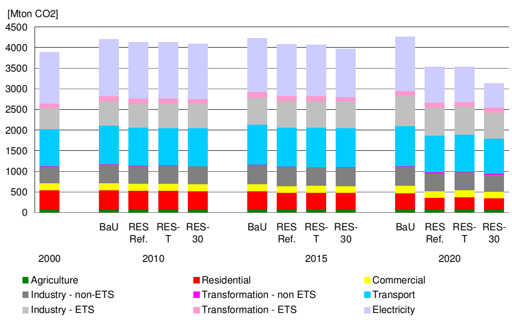
Answer to PQ1 "How to achieve a low cost and low emissions energy mix ?"

The Pan-European TIMES model can provide the cost optimal development of the energy system, given a set of constraints that can reflect policies, primary energy potential per fuel etc. In this sense, cost minimization is at the core of the solution provided. At the same time, the model accounts for GHG emissions produced from energy related activities and includes the modeling of the ETS scheme in Europe. So the achievement of emission reduction targets (at least energy related emissions) are taken into account in the solution.

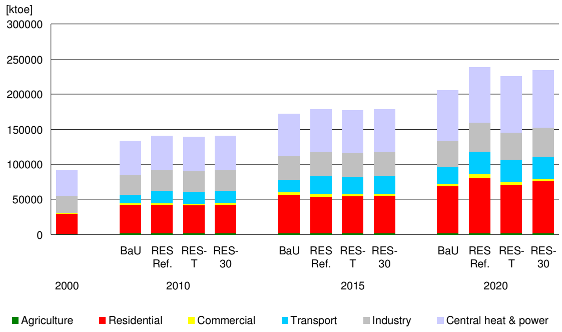
The output data of the Pan-European TIMES model that show the development of the energy sector (both production and consumption) provide direct answers to the Policy Question 1. An example of the type of output is shown in the figures below.



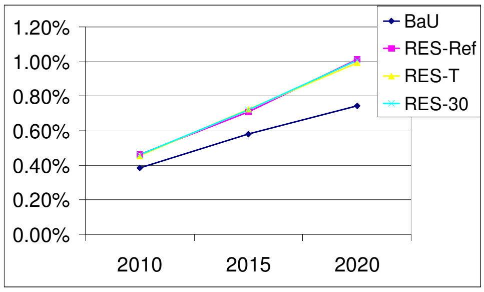
Gross Electricity Production per fuel type for four alternative scenarios



CO2 Emission by sector for four alternative scenarios



Renewable Energy Sources consumption per sector for four alternative scenarios.



Development of the Cost of Renewable Energy Investments and Operating Costs as a Share of the GDP in EU27 in four alternative scenarios

Answer to PQ4: Which are the most competitive low carbon technologies in the medium and long term ?

As was described in the previous section, the TIMES model generator can provide the cost optimal development of the energy system, given a set of constraints that can reflect policies, primary energy potential per fuel etc. A low carbon scenario can be imposed either by constraining the total amount of CO2 emissions or by adding an extra cost (carbon tax) to it. This will lead to a least cost solution of the overall energy system that satisfies a low carbon development constraint in the medium and long term. The PanEuropean TIMES model can be used in such an analysis to show which are the cost competitive technologies that should be used to fulfill the policy of a low carbon energy system.

Answer to PQ5: Where should new energy installations be best located ?

The geographical breakdown of the Pan-European TIMES model is limited to the level of a country, so this question cannot be answered directly at the moment. However the TIMES model generator is flexible and can be used to extent the geographical coverage to regions within countries or even more detailed depending on the existing data. Examples of a national TIMES model with regional breakdown exists (e.g. TIMES –FI) and can be used as an example for the further development of PanEuropean TIMES.

Answer to PQ6: In which R&D areas should a country invest ?

This question is not answered directly by the TIMES based models. However these models present the energy technologies that should be used in order to fulfill the constraints used in the scenario runs. Therefore this will give an indication of the kind of technologies that should be improved and an indication of which R&D areas should be at the focus.

COMPETES

Model Input Requirements and Model Output Results

A. Detailed list:

a. Regions covered by the model.

The new version of COMPETES covers EU countries and some non-EU countries (Norway, Switzerland, Balkanian) at national level as given in figure below. Denmark is divided into two parts that belong to two different non-synchronised networks, while Luxembourg is added to Germany, because there is generally no congestion between them.

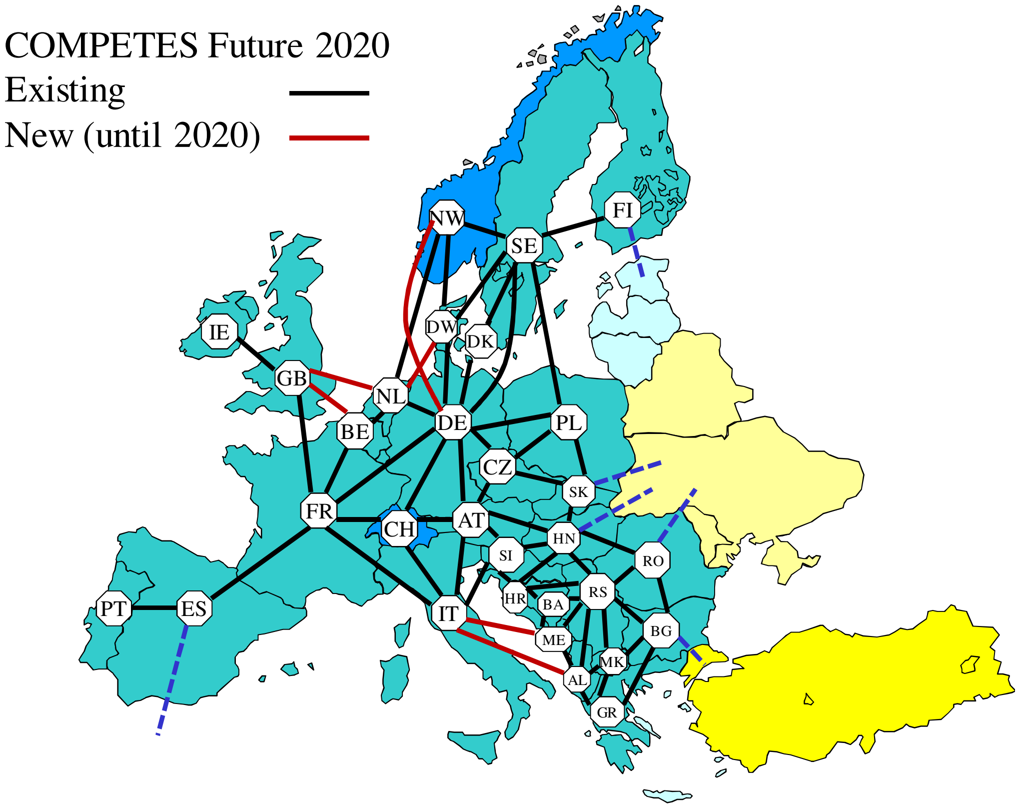


Fig. 1 Geographical scope of COMPETES model

b. Sectors and subsectors covered by the model.
   i. Power sector

c. Primary Energy sources covered by the model (as detailed as possible).
   i. Hard coal and lignite
   ii. Oil
   iii. Natural gas
   iv. Biomass
   v. Waste (municipal, industrial)

vi. Geothermal energy
vii. Wind energy
viii. Solar energy
ix. Hydro energy

d. Demands covered by the model.
   i. Final electricity demand (on an hourly base)
e. Economic drivers used by the model (e.g. GDP, population, etc.)
   i. -
f. Technologies covered by the model.

FUEL	TECHNOLOGY	DESCRIPTION
CONVENTIONAL TECHNOLOGIES		
Derived gas	IC	Internal combustion
Natural Gas	IC	Internal combustion
Natural Gas	GT	Gas Turbine
Natural Gas	CCGT	Combined cycle
Natural Gas	CHP	Cogeneration
Natural Gas	CCGT CCS	Combine Cycle with CCS
Natural Gas	CHP CCS	Cogeneration with CCS
Coal	ST	Steam Turbine
Coal	IGCC	
Coal	IGCC CCS	
Coal	CHP	
Lignite	ST	Steam Turbine
Oil	ST	
Nuclear	-	
RENEWABLE TECHNOLOGIES		
Biomass	Cofiring	
Biomass	Standalone	
Waste	Standalone	
Geo	-	Geotermal
Sun	PV	
Wind	onshore	
Wind	offshore	
Hydro	Conv	Hydro Storage
Hydro	PS	Hydro Pump-Storage
RES	Other	

B. Model/Tools data input.

The below parameters should be specified for the year which is of interest for analysis			
	Input Parameter Name	**Input Parameter Description**	**Units**
GENERAL	Include/exclude loop flow_based network	User-defined parameter to simulate flow-based market coupling or not	
PRIMARY ENERGY SOURCES	Fuel_price	Fuel prices of energy resources for power sector per country	€/Mwh or €/GJ
REGIONS AND INTERCONNECTIONS	NTC	Trading capacity between countries in both directions	MW
	T_up and T_down	Physical interconnection capacity between countries in both directions (T_up is the limit for the direction as the flow, T_down is the opposite direction)	MW
	Susceptance (Optional)	Susceptance of an ACline between countries if flow-based market coupling is simulated	1/ohms
DEMANDS	E_Demand	Final electricity demand, per hour per country	MW
TECHNOLOGIES	Efficiency	Efficiency of technology	%
	Availibility	Availability factor of non-intermittent technology (annual or seasonal)	%
	Capacity	Installed generation capacity per technology and per country	MW
	Must_run generation	Must_run generation per technology per country (inflexible generation)	MW
	VAROM	Variable operation and maintenance cost per technology	€/Mwh
	Loadfactorwon	Hourly load factor time series of wind onshore (availability of wind per hour per country)	
	Loadfactorwoff	Hourly load factor time series of wind offshore (availability of wind per hour per country)	

	Loadfactorsunpv	Hourly load factor time series of sun pv (availability of sun per hour per country)	
	ror	Run of river share of hydro generation per month per country	
EMMISION	CO2 price	EU ETS carbon price for power sector	€/tonne
	Fuel_Emission	CO2 Emission factors per fuel or technology	kg/GJ

C. Model output.

Output Parameter Name	**Output Parameter Description**	**Units**
e.g.		
System cost per country	Short-run marginal cost of system per country per hour	€/hour
Total System Cost	Total cost of the optimal power dispatch (including fuel cost, emission cost, variable and fixed O&M costs, congestion cost)	€ (Selected year)
Generation	Generation per technology per country for selected period in a year	Gwh
Net Imports/Exports	Net import/exports per country for selected period in a year	Gwh
Demand curtailment	Curtailment of demand per country for selected period in a year due to transmission constraints	Gwh
Intermittent RES curtailment	Curtailment of intermittent RES (e.g., wind) per country for selected period in a year due to transmission constraints	Gwh
Flows	Power Trade flows between countries	Gwh
Congestion	% fraction of time congestion occurs per line in a year	
Emissions	CO2 Emissions per country	t CO2e
Congestion price	Marginal Value of the transmission capacity (shadow price)	€/MWh

D. Answers to a Policy Question

A brief description on how the model may contribute to answering these policy questions follows:

1. How to achieve an energy mix that has the maximum societal acceptance?
2. Where should new energy installations be best located?
3. In which R&D areas should a country invest?
4. How should a country develop energy interconnections with other European and non European countries?

Answer PQ1 "How to achieve an energy mix that has the maximum societal acceptance?"

The model cannot help answering this question directly. However, for predefined scenarios of generation and demand developments, the model can help to find the optimal economic solution for generation and transmission of electricity. For given generation and demand scenarios the model finds optimal dispatch of electricity by taking into account the transmission limits and calculates the corresponding emissions and system cost which gives indication of economic benefits and costs of futures with different generation technologies.

The trade-off between the economic benefits/costs versus social implications and political incentives can be compared as a post-processing as a qualitative analysis since quantification of social acceptance is a challenge.

Answer PQ2 "Where should new energy installations be best located?"

The static version of the model does not endogenize optimal installed power generation capacities. However, for given generation and demand scenarios the model finds optimal dispatch of electricity by taking into account the transmission limits and calculates the corresponding emissions and system cost. The static version of the model can be used in answering the following question:

- What is the impact of different generation developments in each country on the system costs?

To answer this question, different scenarios for generation developments can be run. Each scenario will result in a different power generation dispatch and mix in each country . By comparing the resulting generation and emission costs of the scenarios, one can learn the marginal benefit and cost of an additional generation technology in each country.

Moreover, the dynamic version of the model is currently being developed. In dynamic version, the additional conventional generation capacity and transmission capacity will be endogenized. As a result, the dynamic version of the model will be able to answer the following question: For given developments of renewable energy and carbon price in power sector in each member state (which mainly depends on the targets and different policy implementations):

- What level of additional conventional capacity are required (which copes with intermittent RES generation) in each member state country to achieve minimum generation and emission cost?

Answer PQ3 “In which R&D areas should a country invest?”

The model cannot help answering this question.

Answer PQ4 “How should a country develop energy interconnections with other European and non European countries?”

COMPETES model can answer this question in several aspects. The output of the the model includes the magnitude and direction of the trade flows between countries as well as the congestion and the marginal value of transmission capacity between countries (e.g., shadow price of transmission constraint which represents the decrease in system cost for one additional MW of trasnmission capacity). Under different generation and demand scenarios, the interconnections which needs extension can be prioritized based on the marginal value of transmission capacity and the % fraction of time congestion occurs per line in a year. Moreover with an hourly representation, the impact of intermittent generation on the flows and congestion patterns can be identified.

Moreover as mentioned in the previous question, the dynamic version of the model is currently being developed. In dynamic version, the model will be able to calculate the additional transmission capacity required. With the dynamic COMPETES model, we would like to address what the new strategies for cross-border capacities and accompanying regulation changes would be by answering the following question:

1. What **level of cross-border network extensions** are required to meet different energy generation scenarios with high level of production from carbon dioxide neutral energy sources?
2. What **type of future networks** will be most cost effective and robust to achieve these cross-border extensions? Are we looking into a future with HVDC overlay on top of existing network or with significant reinforcement s of existing AC networks? (This question will be answered by ECN from an economical point of view rather than a technical point of view)

Finally, few non-European countries are included in COMPETES model as seen in Figure 1. So the interconnections between these non-European countries can be analyzed as well as the European countries.

Climate Bonus

Model Input Requirements and Model Output Results

A. Detailed list:

a. Regions covered by the model.
   All countries – level of detail: National, the pilot model is done in Finnish context
b. Sectors and subsectors covered by the model.
   The pilot model covers:
   - Food
     - Fruit and berry foods
     - Vegetable food
     - Greenhouse vegetables
     - Salads
     - Potatoes
     - Other vegetables
     - Grain and bakery products
     - Rice
     - Milk and milk products
     - Cheese
     - Fat and fat products
     - Eggs
     - Fish food
     - Meat food
     - Beef
     - Other meat
     - Coffee and tea
     - Pure juice
     - Water, soft drinks, juices
     - Alcohol drinks
     - Sugar, sweets
     - Baby food
     - Others
   - Energy consumption of transport
     - Public transport
       - ship transport
       - air transport
       - motor vehicles
     - Household transport

- Energy consumption of housing
    - Electricity
    - District heat
    - Fuel oil
    - Other fossil fuels
- Other consumption
    - Clothes and shoes
    - Furniture
    - Housing – real property services
    - Housing devices
    - Vehicles – buying
    - Vehicles – using
    - Books, magazines
    - ICT services
    - Health services
    - Personal cleaners
    - Sanitary papers
    - Detergents
    - Restaurant services
    - Hotel services
    - Hairdressing services
    - Other goods
    - Other services
- Emission compensation

c. Primary Energy sources covered by the model (as detailed as possible).
    - Electricity (CO_2 emission coefficient included, takes into account the primary energy source e.g. renewable, nuclear or fossil)
    - Combined heat and power production (district heating)
    - Fossil fuels

d. Demands covered by the model.
    --

e. Economic drivers used by the model (e.g. GDP, population, etc.)
    --

f. Technologies covered by the model.
    - Motor vehicles
    - All kinds of technologies used in producing various consumption products
    - Electricity heating
    - District heating

- Other heating technologies

B. Model/Tools data input.

Categories	**Input Parameter Name**	**Input Parameter Description**	**Units**
GENERAL			
REGIONS			
SECTORS	Food	Every food item is classified into 23 classes, which all have a specific emission factor, an estimation of the emissions caused by a certain product is calculated based on the weight of the product	kgCO2ekv/kg, kg
	Public transport	Transport distances, traveller amounts (filling rate of the vehicles), prices; the model includes the most commonly used public transport emission factors, but emission factors can also enter manually	km, kgCO2ekv, kgCO2ekv/€
	Household transport	Bought fuel oil	l
	Household energy consumption	estimation of electricity and district heat consumption, costs,	kgCO2ekv/€, kgCO2ekv/kWh, kgCO2ekv/ll

		emission factors for electricity and district heat	
	Other consumption	prices and emission factors for every products and items	kgCO2ekv/€
DEMANDS			
TECHNOLOGIES			
Emission	Emission compensation	Commercial emission compensation services (e.g. in flying business)	kgCO2ekv/€

C. Model output.

Output Parameter Name	**Output Parameter Description**	**Units**
Food	% of the total CO2 emissions and CO2 emissions per euros	%, kgCO2ekv/€
Transport energy consumption	% of the total CO2 emissions and CO2 emissions per euros	%, kgCO2ekv/€
Household energy consumption	% of the total CO2 emissions and CO2 emissions per euros	%, kgCO2ekv/€
Other consumption	% of the total CO2 emissions and CO2 emissions per euros	%, kgCO2ekv/€
Total	% of the total CO2 emissions compared to other similar households (in Finland and in the world and EU target) and CO2 emissions per euros	%, kgCO2ekv/€
Emission compensation	% of the total CO2 emissions and CO2 emissions per euros	%, kgCO2ekv/€

D. Answers to a Policy Question

Your model was ranked among the top in answering the ATEsT policy question[s]:

9. How to achieve a low cost and low emissions energy mix ?
10. How to achieve an energy mix that maximizes employment opportunities ?
11. How to achieve an energy mix that has the maximum societal acceptance ?
12. Which are the most competitive low carbon technologies in the medium and long term ?
13. Where should new energy installations be best located ?
14. In which R&D areas should a country invest ?
15. How should a country develop energy interconnections with other European and non European countries ?
16. How to improve energy efficiency ?

A brief description on how the model may contribute to answering these policy questions follows.

PQ1 How to achieve a low cost and low emissions energy mix?

The primary aim of the Climate Bonus model is to show to a customer his/hers CO2 emissions based on his/her actual purchases, and collecting a customer database on produced CO2 emissions in order to gain bonus points for as low CO2 production as possible. By following the model output kgCO2ekv/€, for instance in the housing energy consumption, the model can give information on low cost and low emission energy mix, but the model is not intend to do it.

PQ3 How to achieve an energy mix that has the maximum societal acceptance?

The societal acceptance is possible to measure according to Climate Bonus by following the consumption data base produced in the model, and based on the information included in that data base analysing what kind of transport or household energy choices consumers have made. This may however not show the absolute societal acceptance (what the society encouraged to do), but reflects the individual acceptance (consumer).

Source: Hyvönen, K., Saastamoinen, M., Timonen, P., Kallio A., Hongisto, M., Melin M., Södergård, C and Perrels, A. 2009. Kuluttajien näkemyksiä kotitalouden ilmastovaikutusten seuranta- ja palautejärjestelmästä. Climate Bonus –hankeraportti (WP5). VATT Tutkimukset 1443:4.

RESOLVE-E

<u>Model Input Requirements and Model Output Results</u>

A. Detailed list:

a. Regions covered by the model.
    i. All EU countries + Norway – level of detail: National

b. Sectors and subsectors covered by the model.
    i. Power sector (actually a subsector, since only the renewable part of the power sector is covered)

c. Primary Energy sources covered by the model (as detailed as possible).
    i. Wind energy
    ii. Solar energy
    iii. Geothermal energy
    iv. Hydro energy
    v. Wave energy
    vi. Tidal energy
    vii. Wood pellets
    viii. Saw dust
    ix. Torrefied and pelletisized Straw
    x. Torrefied and pelletisized Biomass
    xi. Torrefied and pelletisized Wood
    xii. Chipped prunings
    xiii. Wood chips
    xiv. Pure vegetable oil
    xv. Used fats/oils
    xvi. Black liquor
    xvii. Municipal solid waste
    xviii. Dry manure
    xix. Wet manure + co-digestate
    xx. Cereals
    xxi. Forage maize
    xxii. Verge grass
    xxiii. Animal waste
    xxiv. Landfill gas
    xxv. Sewage sludge

d. Demands covered by the model.
    i. Final electricity demand

e. Economic drivers used by the model (e.g. GDP, population, etc.)
    i. -

f. Technologies covered by the model.

i. Wind onshore
ii. Wind offshore
iii. PV
iv. Solar thermal electricity
v. Tidal electricity
vi. Wave electricity
vii. Large hydro power (>10 MW_e)
viii. Small and medium hydro power (<10 MW_e)
ix. Geothermal electricity
x. Biomass CHP
xi. Biomass cofiring
xii. Biomass combustion
xiii. Biomass digestion
xiv. Biomass gasification

B. Model/Tools data input.

Categories	Input Parameter Name	Input Parameter Description	Units
GENERAL	ReferencePrice	Reference whole sale electricity price, per country, per year	€ct/kWh_e
	ReferenceGasPrice	Reference gas price	€/GJ
	Taxrate	corporation tax	%
	InflationRate	EUROSTAT definition of inflation	%
REGIONS	Inclusion	Indicate if and from which year on countries can share their potentials and RES-E targets	
SECTORS	-	-	-
DEMANDS	ElectricityConsumption	Final electricity demand, per year, per country	GWh_e
TECHNOLOGIES	ExclusionOutput	Exclusion of a certain country,technology,band combination from the model	
	Realisations	Statistical RES-E production per technology,country,year	GWh_e
	LeadTime	Lead time of a technology	years
	PipelineSucceed	Factor needed to calculate how much of the realistic potentials is really looked at by investors/potentially in the pipeline	%
	Intermittence penance	Intermittence penalty per	€ct/kWh_e

		country,technology	
	Investment	InvestmentCosts in start year	€/kW
	Fixom	Fixed yearly O&M costs	€/(kW*yr)
	Varom	Variable O&M costs	€ct/kWh
	BiomassPrice	Biomass feedstock price	€/GJinput
	Depreciation rate	Yearly depreciation rate of the investment	%
	Debt share	Debt share of the investment	%
	Debt rate	Debt rate of the investment	%
	MinRoE	Minimum Return on Equity	%
	LoanPeriod	Duration of the loan	%
	Full load hrs	Yearly full load hours of a technology	hrs/yr
	Electrical efficiency	Electrical efficiency for biomass technologies	%
	Thermal efficiency	Thermal efficiency of biomass CHP technologies	%
	Reference thermal efficiency	Reference thermal efficiency of biomass CHP technologies	%
	Economic lifetime	Economic lifetime of a technology	yrs
	Technlife1	Technical lifetime of a technology	yrs
	Potential_TJ	Primary biomass potential per type of feedstock	TJinput
	Input value	Main factor determining the realistic potential per country,technology,band in 2040	Unit differs per technology.
	Value conversion factor Input	Conversion factors to come level by level from the main factor of the realistic potential to the final realistic potential in GWh	Unit differs per technology and per assessment level
	Maturity start	Year when a technology gets into the market (so beyond demonstration phase)	
	Full maturity	Year when a technology is considered as fully mature	
	STD electricity	Relative standard deviation in the electricity price, used for	

	commodity price	calculation of risk premium	
	Production volume STD	Relative standard deviation in the yearly production of variable technologies, used for calculation of risk premium	
	Fuel costs STD	Relative standard deviation in biomass feedstock prices, used for calculation of risk premium	
	Investment STD	Relative standard deviation in investment costs, used for calculation of risk premium	
	O&M fixed STD	Relative standard deviation in fixed O&M costs, used for calculation of risk premium	
	O&M var STD	Relative standard deviation in variable O&M costs, used for calculation of risk premium	
Technological progress	Progress Ratio	Progress ratios	
Policies	*Several*	The following kind of support policies are possible: -Feed in tariff -Feed in premium -Fixed premium -Bidding systems -Quota obligations -Investment subsidies -4 types of financials incentives	
Emission	-	-	-

C. Model output.

Output Parameter Name	Output Parameter Description	Units
RES-E projection	Projection of RES-E developments, capacity and production. Can be expressed per country,technology,band,year or any sum over these sets.	MW and GWh
Biomass resource mix	Projection of biomass utilization per feedstock category. Can be expressed per country,technology,year or any sum over these sets.	GWh_e and GJ_{input}
Cost developments	Development of several cost (investment costs, O&M costs, levelized production costs).	€/kW, €/kWh

	Can be expressed per country,technology,band,year.	
Total additional costs	Total additional costs wrt whole sale electricity price. Can be expressed per country,technology,band,year or any sum over these sets.	€ or €ct/kWh
Utilization of specific support measures	Utilization of a specific RES-E support measure	GWh_e
Cost effectiveness of support measures	Average additional costs per kWh for a support measure	€ct/kWh
Realization effectiveness of support measures	Realized RES-E production per measure. Has more value if compared with alternative measures	GWh
TradeFlows	Trade of green certificates between countries	GWh/yr

D. Answers to a Policy Question

The model was ranked among the top in answering the ATEsT trail policy questions:

1. How to achieve a low cost and low emissions energy mix?
2. How to achieve an energy mix that maximizes employment opportunities?
3. In which R&D areas should a country invest?
4. How to improve energy efficiency?

A brief description on how the model may contribute to answering these policy questions follows.

Answer PQ1 "How to achieve a low cost and low emissions energy mix ?"
The model doesn't cover emissions, but if emission factors are available it is not such a difficult task to implement this. Note that RESolve-E only covers the renewable part of the electricity sector. Since the fossil mix also has a huge influence on the emissions, the model seems not well able to cover the emissions part of the question.
The model can be used in answering a relevant subquestion "How to achieve a low cost RES-E mix, which corresponds to a certain RES-E share?" To help answering this question different policy scenarios can be run. Each scenario will result in a different RES-E path, different RES-E mix and different average production costs (in €ct/kWh) in a target year. By comparing the scenarios one can learn how a low cost pre-defined share of RES-E can be achieved.

Answer PQ2 "How to achieve an energy mix that maximizes employment opportunities?"
The model can't help in answering the subquestion "which energy mix maximizes employment opportunities?". If the answer to this question is

available, the model can help in answering another subquestion “How to achieve this energy mix?”
Achieving a pre-defined energy mix can be investigated by the model since one can play with the following variables:

- When will a technology take up
- How quickly will this happen (the steepness of the development path)

One can indirectly play with these variables by tuning the incentive policies.

Answer PQ3 “In which R&D areas should a country invest?”
The model uses ‘static’ progress ratios in the calculation of cost development. These progress ratios are exogenous and not determined endogenously. The progress ratios that the model uses correspond more to ‘learning by doing’, so the cost reductions are reached by employement. The model doesn’t cover ‘learning by searching’. For this reason it will be difficult help answering this question. The model can only help somewhat qualitatively in case there is a huge potential for a certain technology, but the technology is still very expensive. If extra R&D is invested in areas related to that technology the progress ratio of a technology might be improved.

Answer PQ4 “How to improve energy efficiency?”
RESolve-E can’t help in any aspect of this policy question and there is no output data that is relevant for answering this question. The reason is that the electricity demand is an exogenous parameter to the model.

IER Transmission model

<u>Model Input Requirements and Model Output Results</u>

A. Detailed list:

a. Regions covered by the model.
   - a.i. Germany – level of detail: Substations

b. Sectors and subsectors covered by the model.
   - b.i. Electricity Generation
   - b.ii. Electricity Transmission

c. Primary Energy sources covered by the model (as detailed as possible).
   - c.i. Lignite
   - c.ii. Coal
   - c.iii. Natural gas
   - c.iv. Oil
   - c.v. Biomass
   - c.vi. Wind energy
   - c.vii. Solar energy
   - c.viii. Hydraulic energy
   - c.ix. Divers

d. Demands covered by the model.
   - d.i. Electricity consumption of end users
     - d.i.1. Residential
     - d.i.2. Industry
     - d.i.3. Others
   - d.ii. Consumption of pumped hydro power plants

e. Drivers used by the model

f. Technologies covered by the model.
   - f.i. Power Sector
     - f.i.1. Electric Power
       - f.i.1.a. Natural Gas Combined Cycle
       - f.i.1.b. Gas Turbine (peak)
       - f.i.1.c. Coal Steam Turbine
       - f.i.1.d. Diesel Turbine(peak)
       - f.i.1.e. Nuclear 3rd generation
       - f.i.1.f. Nuclear 4th generation
       - f.i.1.g. Wind onshore
       - f.i.1.h. wind offshore
       - f.i.1.i. PV

f.i.1.j. Small - hydro run of river

f.i.1.k. Hydro Pump Storage

f.i.2. Cogeneration Power plants – Autoproducers

f.i.2.a. Gas combined cycle

f.i.2.b. Coal steam turbine (condensing)

f.i.2.c. Gas combined cycle backpressure

f.i.2.d. Coal combined cycle backpressure

f.i.2.e. Biomass steam turbine

f.i.2.f. Gas internal combustion engine

f.i.3. Electricity transmission:

f.i.3.a. 380 kV transmission line

f.i.3.b. 220 kV transmission line

f.i.3.c. 380/220 kV transformer

B. Model/Tools data input.

	Input Parameter Name	**Input Parameter Description**	**Units**
	e.g.		
GENERAL	PREF	Reference Active Power	Value in MVA
	TRM	Transmission reliability margin	Percentage of total transmission capacity
	Resstartlevel	Initial level of water reservoirs	% of total reservoir fill level
Power stations	Generation capacity	Maximal power output	Unit of Power / MW
	Minimal power output	Minimal power output required for stable operation of power plant	Unit of Power / MW
	EFFOPT	Efficiency at maximal power output	percentage
	EffMin	Efficiency at minimal power output	Percentage
	Fueltype	Used Fuel for electricity generation	Number
	EmisKoef	Coefficient for the share of emissions	Tons/Mwh
Leitungen	Start	Starting point of line	Binär (1=ja/0=nein)
	Ende	Endpunkt der Leitung	Binär (1=ja/0=nein)
	Resistanz	Wirkwiderstand	Unit of Resistance / Ohm
	Reak	Blindwiderstand	Unit of Resistance 7 Ohm
	Limit	Maximal power flow on line	Unit of Power / MW
	Voltage	Level of Voltage	Unit of voltage / V
	INVCOST	Investment cost per technology	€ per line installed
Pump storages	Speich_Vol	Maximal level of water reservoir	Unit of Energy / MWH
	Pumpkap	Pumping capacity	Unit of Power / MW
System parameters	Fuelprice	Prices for fuels and emission certificates	€ per MWh fuel or ton CO2
	POSRES, NEGRES	Reserve requirement	Unit of Power (MW

C. Model output.

Output Parameter Name	Output Parameter Description	Units
System cost	Detailed Discounted total cost of the optimal system	€'(base year)
Energy balance	Injection/withdrawl at each node	MW
	Power station output at each node	MW
Power station	Fuel consumption of each power station	MWh
	Emissions of each power station	Ton CO2
Optimal Investment plan	Installed Generation Capacity of each technology for each period of the study	Units of installed capacity
	Installed transmission Capacity of each technology for each period of the study	Units of installed capacity
Powerflows	Power flow on each line during each period	MW

D. Answers to a Policy Question

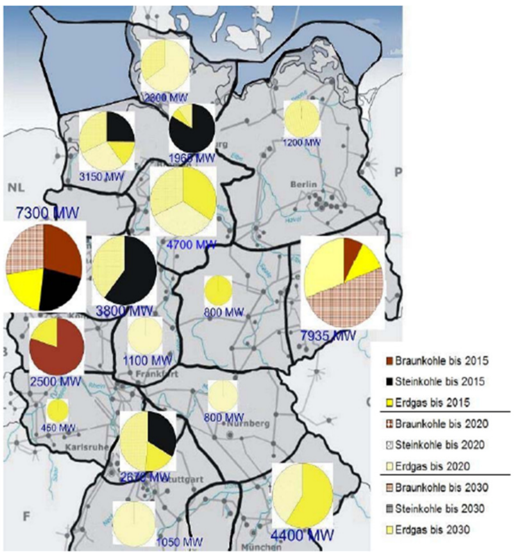
The model was ranked among the top in answering the ATEsT trail policy question[s]:

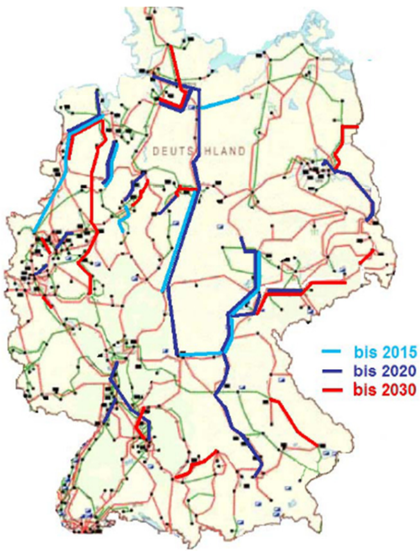
1. How to achieve a low cost and low emissions energy mix ?
3. How to achieve an energy mix that has the maximum societal acceptance ?

Answer to PQ1 "How to achieve a low cost and low emissions energy mix ?"

The IER Transmission model provides the cost optimal development of the electricity system, given certain boundary conditions. Among these boundary conditions are fuel prices, the prices for CO2 emission certificates, the available technologies for investment, the shares of renewable energy sources, etc. In addition to investment cost, the cost for operating the power system, especially fuel costs are included in the cost minimization problem.

The output data of the IER transmission model shows development of the power sector (electricity generation and transmission capacity) which is a direct answer to question 1. Some example outputs are shown below





Answer to PQ3 “How to achieve an energy mix that has the maximum societal acceptance ?”

The IER Transmission has got a high spatial resolution. If the investment in certain technologies at specific places is impossible due to the lack of local acceptance or because other reasons (national parks, etc.), these options can be removed for the model and are not part of the optimization anymore. Removing those options is equivalent to adding additional constraints that assure the local acceptance of the selectable expansion options.

If local barriers for the development of certain technologies are not known a priori, the power system expansion results by the model can be used for further investigation on that issue (questionaires, surveys,etc.).

MECHanisms

Model Input Requirements and Model Output Results

MECHanisms is a collection of tools, which when combined provide a better framework for the implementation of energy related projects. As a tool is project oriented in a very broad sense[2] and offers a mix of managerial techniques with respect to societal and behavioral issues and particularities. This kind of approach deviates from the traditional notion of models, so a listing of input/output will not work as well as to the other models. Furthermore, almost the majority of the "input" used in MECHanisms is of qualitative nature and so does the output, which complicates the picture even more. For a better representation of the tool in general it has been chosen the following table. It is important to note that the methodology overall is divided into steps, which are sequential processes of the tool. For each step are given : 1. Input/starting point, 2. Specific Tool which assess input 3. Output/goal

A. Answers to a Policy Question

The model was ranked among the top in answering the ATEsT trail policy questions:

2. How to achieve an energy mix that maximizes employment opportunities?
3. How to achieve an energy mix that has the maximum social acceptance
4. Which are the most competitive low carbon technologies in the medium and the long term
5. Where should new energy installations be best located
6. In which R&D areas should a country invest
8. How to improve energy efficiency

A brief description on how the model may contribute to answering these policy questions follows.

Answer PQ2 "How to achieve an energy mix that maximizes employment opportunities?"

It has been mentioned above that MECHanisms is a strictly project related tool. As a consequence it cannot give indications on what the energy mix that maximizes employment opportunities would be. However, if the tool would have been applied in the implementation of numerous diverse projects then it could provide a useful database that could help in spotting that energy mix which could maximize employment opportunities. Furthermore it can provide realistic indication on the relationship between employment and the deployment of certain technologies or actions that target in changing energy behavior. This information would be of great importance when combined

[2] For instance changing energy behavior in a workplace

with other models that could treat these issues with stronger integrated approach.

Answer PQ3 How to achieve an energy mix that has the maximum social acceptance**”**
The tool can offer significant help in answering this policy question, especially if the tool had been applied in the implementation of numerous diverse projects. One of the major pillar of the tool is to deal with social acceptance of the relevant target groups. Assuming the availability of a database, which contains the application of numerous projects,and even more if certain metrics have been established to measure the social acceptance of projects in different locations, then important information can accrue. This information will bring critical insight in understanding social trends in accordance with certain technologies or initiatives. Furthermore, best practices under given conditions can be traced, examined and methodized appropriately. Such a development could also help in maximizing social acceptance. What however becomes undisputed for MECHanisms, is the extraordinary contribution in maximizing social acceptance when a specific project is implemented.

Answer PQ4 “ Which are the most competitive low carbon technologies in the medium and the long term?”
MECHanisms as a standalone tool can’t answer at such kind of policy question. Even if the tool had been applied in numerous diverse projects and a relevant database had been constructed, still it couldn’t support in finding the competitive low carbon technologies in the medium and long term. The reason for this is that MECHanisms is static in time, and the horizon of the model finishes when each project is finished. What however could be a contribution is to provide indications about externalities related with social issues. Hence the real cost of the deployments of technologies would be more complete.

Answer PQ5” Where should new energy installations be best located ?”
If MECHanisms had been applied in numerous diverse projects and a relevant database had been constructed, then information about the deployment rates of technologies or initiatives in different regions could provide indication on where it is optimal for new energy installations to be located. As a single tool it can’t give significant insight but if combined with other models, then maybe it can contribute in refining the optimal solution. Again in this case, emphasis should be given in the correlation between societal/behavioral issues and geographical information.

Answer PQ6 “In which R&D areas should a country invest ?”
MECHanisms can’t help in answering this policy question because the tool does not deal with any aspect of R&D procedures.

Answer PQ8 “How to improve energy efficiency?”
Energy efficiency projects are in the core of the projects that MECHanisms tool refers to. It can cast the whole chain of an energy efficiency project implementation, giving emphasis in understanding behaviour patterns and identifying possible obstacles or opportunities arising from societal issues. Furthermore, if the tool had been applied in numerous diverse energy efficiency projects and a relevant database had been constructed, then, with certain metrics of social acceptance, the energy efficiency projects could be classified according to : capability of penetration, acceptance by the society, energy efficiency capacity, managerial difficulties, geographical peculiarities etc. Finally, a well-informed database that contains a sufficient number of projects implemented in the past, can provide information on how to construct learning rates per technology or initiative.

Understand the problem			
	Input	Tool	Output
Step 1 : Pinpoint the problem	Problem description	Problem tree	Problem redefinition Aspects/agents traced
Step 2: Get to know target group	Initial information about the target group	1.Checklist 2. Small scale research(e.g. interviews, field observations, survey studies, focus groups etc)	1. better understanding of the target group 2. Optimal choice of the appropriate method to analyze target group 3. Quantify necessary research efforts according to the project needs
Step 3: Understand the context	Key features of the projects' context	Forcefield analysis	1. Trace possible opportunities or obstacles 2. Assess project's context

Step 4: Is the time right?	Identify issues regarding time about project implementation	Brainstorming sessions about time(identify existing policies, local initiatives, technology deployment perspectives, possible partnerships or media campaingns)	Assess risk regarding time and respond effectively
Step 5: Identify relevant stakeholders	Create a mapping of possible stakeholders	1. Visualize stakeholders 2. Strategic assessment of partnerships 3. Network to promote durable change	Realistic assessment of - Stakeholders - Partnerships - Networks to guarantee the sustainability of the project
Plan & do			
	Input	Tool	Output
Step 6: Define goals and manage external demands	Goals of the project	1. Define goals and manage external demands 2. Trace milestones of the project 3. Quantify and qualify project's success	-define success criteria -Setting milestones -methods to track progress of projects implementation
Step 7: Plan with and for	Different aspects of the project	Assess project flexibility	1. Find fix and flexible aspects of the projects 2. Find the appropriate balance between bottom up/top down approach for project

your target group			implementation
Step 8: Select and adapt your instruments	Possible instruments to use	1.Tailor instruments to context 2.Digital instrument planner	Decide which instrument to use based on assessments of their efficiency and adaptability
Step 9: Test your ideas	Project Plans	Testing your project plans	Revise plans and ideas
Step 10: Engage your target Group	Target Group	1. Tools for influencing a. Habitual behaviors b. Energy efficiency investments 2. Tools for engaging communities	Methods and instruments appropriately chosen and applied to engage target groups efficiently
Step 11: Possible feedbacks of the project on the target group(s)		Motivate through feedback	-Find out which target group needs feedback on what -select the right time -select the best format and media for the target group -tailor and adapt the message to the needs and interests of the target group -Reassure positive impact of feedback procedure

Evaluate & learn			
Step 12: Get some feedback	Feedback	Active collection of feedback	-Choose stakeholders to take feedback from - Collect feedback -Structure feedback -Revise project according to the received feedback
Step 13: Evaluate and improve	Success criteria, milestones for periodic evaluation	Reflective table for evaluating and improving	Trace necessary improvements/changes to fulfill all the success criteria that have been set
Step 14: Develop a learning culture	Evaluation results	1. Mid project self evaluation 2. End of project reflection questions	1. Enhance the functional strengths of your organization 2. Become a carrier of systemic change